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RADIOACTIVE WASTE MANAGEMENT COMMITTEE

PERFORMANCE ASSESSMENT ADVISORY GROUP (PAAG)

Summary Record of the First meeting of the NEA Working Group on the Identification and Selection of Scenarios for Performance Assessment of Nuclear Waste Disposal

Paris, 12th-14th October 1987

Present:

B. Goodwin, Canada
P. Escalier des Orres, France
J. Marciano, T. Foult, France (part of time)
K. Andersson, Sweden
P. Zuidema, Switzerland
D. Hodgkinson, UK (Chairman)
R. Cranwell, R. Guzowski, USA
D. Galson, USA
S. Carlyle, NEA (part of time)
J.P. Olivier, NEA (part of time)
C. Thegerström, NEA

The first meeting of the Working Group on Scenarios was held in Paris on 12th-14th October 1987. A detailed report is given in the record below. In summary the following was accomplished during the meeting.

* Dr. David Hodgkinson, UK, was elected as chairman of the Group

* Experiences in Member countries on scenario identification and selection were reviewed based on presentations by participants at the meeting and on scenario questionnaire responses. A substantial amount of material on performance assessments and scenario identification/ selection is thus available. It will be further compiled by the Secretariat with the aim of obtaining a complete and systematic presentation (catalogue) as a basic background information in this field.

* General discussions were held covering the following main subject areas

  - the scenario concept
  - the logical framework for performance assessment and scenario identification/selection
  - approaches and methodologies
  - selected topical issues (time-perspectives, probabilities, human intrusion, bounding analysis, etc.)

* The group arrived at a common general approach to the procedure of identification, screening and selection of scenarios.

* Guidance on what should be meant by a scenario was given by the group based upon which the NEA Secretariat will draft definitions on "scenario-terminology".

* A detailed preliminary table of contents for the final document was developed and a first draft will be available at the next meeting, 9-11 May 1988. An overview paper (about 20 pages) will be prepared by the working group Chairman for presentation at the next PAAG meeting (see below).

* A preliminary programme was set up for a one-day workshop on scenarios at the next PAAG meeting 25-27 January 1988. PAAG will then get the opportunity to discuss in detail the NEA work on scenarios and to give further comments on this work.

Item 1: Opening of the meeting - Election of the Chairman

1 Participants were welcomed to this first meeting and Dr. David Hodgkinson, UK was invited to be the chairman of the working group. The agenda for the meeting was approved.

Item 2: Remarks by the Chairman and the NEA Secretariat

2. In his remarks the Chairman pointed out that the discussions should be kept on a general level and not go to much into details of particular scenarios. The concept of scenarios should be explored and the group should try to establish a logical framework for the discussion of scenario identification and selection. He also said that it would be wise already at this first meeting to think about the content of a final document to be produced by the group.

3. Mr. Thegerström recalled the general objectives of the working group on scenarios as agreed by PAAG and RWMC. They would be:

> "to consider, at an international level, issues related to the identification and selection of scenarios for performance assessment of radioactive waste disposal in order to promote consistency in approaches and methodologies" [PAAG/DOC(87)2 annex 3].

The scope of the work had been defined as identification and selection of scenarios for post-closure assessment of disposal of all types of radioactive waste. First priority, however, would be given to deep disposal of long-lived wastes. The work should result in a state-of-the-art report, reflecting the discussions and conclusions of the working group.

4. Mr. Thegerström mentioned that the scenario issues were considered by PAAG as a high-priority area which must be strongly linked directly to PAAG. A progress report from the working group should be presented to PAAG at its next meeting in January 1988 to get further directions and priorities from PAAG for the NEA work on scenarios.

Item 3: Review and discussion of work done/being done in Member countries

5. Participants briefly reviewed the work on scenarios being done within their country and/or organisation.

6. Mr. Cranwell and Guzowski described the methodology developed at Sandia for selection of scenarios. The procedure is schematically illustrated in figure 1 (Annex 1) attached. (From NUREG/CR-1667, SAND80-1429). This methodology has been applied for demonstration purposes on concepts for disposal in salt, tuff and basalt. It has also been applied recently in the performance assessment of the WIPP facility. The basic documents on this methodology and its application will be sent by Cranwell to the other participants of the NEA Working Group on Scenarios. He will also try to obtain a scenario questionnaire response from the WIPP-project.

7. Mr. Galson gave further comments on the approach by USNRC on scenario identification/selection. NRC sponsors the work by Cranwell et al. at Sandia. The aim is to develop a generic methodology that could be established by rule-making and that would then have to be followed. This work will proceed over the coming two years and the NEA initiative is therefore very timely for NRC.

8. Mr. Andersson, Sweden, briefly reviewed Swedish experiences referring to the answers given to the NEA questionnaire. He said that there was a strong need for the work now initiated by NEA and that he expected that it could provide a systematic background and guidance for Member countries. He stressed the need for a logical framework for the scenario identification/selection procedure and its relations to and distinctions from other parts of the system performance assessment.

9. Mr. Escalier des Orres, France, highlighted French work on scenarios within the framework of PAGIS, CEC. He discussed the importance of tectonic, seismic and climatic effects for sites in clay, bedded salt and granite. He also mentioned the important work by an expert group (chaired by Prof. Goguel) set up by the French authorities to give guidelines and advice in this context.

10. Mr. Goodwin, Canada, first described regulatory criteria in Canada and their implications on scenario selection. They call for quantification of scenario probabilities and an estimated individual risk of less than 10^{-6} serious health effects per year during a time period of 10^4 year. He reviewed briefly experiences on scenario identification/selection and

performance assessment approaches referring to the detailed Canadian responses to the questionnaire. He pointed out that the quantitative analysis is done with the help of the SYVAC code but that some scenarios are evaluated separately in a qualitative way.

11. Mr. Zuidema, Switzerland, commented briefly on the approach by NAGRA in identification and selection of scenarios for the project Gewähr study. He described the systematic approach and classificaton used and he pointed out the link between how scenarios are selected and the available tools for modelling.

12. Mr. Hodgkinson, UK, described work being done for UK Nirex's previous plans for shallow disposal of low level waste. He pointed out the significance of low levels of α-activity for the long-term safety assessments and he stressed the need to analyse also other effects than transport by groundwater like intrusion by people, animals or plants or gas generation and release.

13. Mr. Foult, France, described the assessments by ANDRA of shallow disposal in France. Institutional control is supposed to be maintained for at least 300 years. In the assessments it is assumed that after that period the use of the site is unrestricted. Human intrusion scenarios with people living or drilling wells at the site appear to be the most critical (limiting).

14. The group reviewed questionnaire responses with the help of table 1 (Annex 2) attached, which gives a brief summary of responses received at NEA up to this date. It was noted that an important and substantial background material on major safety assessment studies and scenario analysis in Member countries is now at hand through the good response to the questionnaire. Further collection of additional questionnaires and compilation of the information should be made.

Item 4: General Discussion

15. During the second day of the meeting the group had an open and wide ranging discussion of all topics previously identified or raised during the first day presentations. In summary the discussions centered around the following main subject areas:

- the scenario concept
- the logical framework for performance assessment and scenario identification/selection
- the general approaches and methodologies for identification and selection of scenarios
- selected topical issues.

16. The group discussed the different concepts of what a scenario is. It agreed that a broad view should be adopted in the scenario definitions. As an example "radionuclide release from the near-field to the groundwater and solute or colloidal transport through the geosphere to the biosphere" would constitute a broad definition of a typical base-case scenario. There would then be many variations when models and input data are specified in the consequence analysis of this scenario. It was recognized that there is a

gradual transition from scenario identification/selection to specification for modelling and consequence analysis. The group felt however that the choice of conceptual models and input parameters is not part of scenario identification/selection.

It was further recognised that the concept of sub-scenarios (for the near-field, geosphere and biosphere) could be useful to include in the terminology. It was also noted that it could not be excluded that particular performance assessment approaches, like simulation and modelling with stochastic methods of an entire possible future of the disposal system and its environment, would require a terminology adapted to that approach.

It was decided that the NEA Secretariat would draft a set of definitions for the terminology needed and send it to the participants for comments.

17. The role of scenario identification and selection in the overall framework of performance assessments was discussed. Based on these discussions, schematic diagrams will be developed (see Annex 3) to show the linkages and interactions between the different elements of performance assessment in general and scenario identification/selection in particular. The need for an iterative process was stressed. That means that it is needed to define a disposal system; identify and select scenarios; analyse these and based on the results adjust the system and/or the scenario selection and the consequence analysis methodology; make complementary assessments; and in this way gradually approach an "optimized" disposal system and a "mature" safety assessment of it.

18. Approaches and methodologies for identification and selection of scenarios were discussed in detail. It was concluded that expert judgement is fundamental as a basis for developing scenarios. A systematic procedure (for instance as illustrated in Annex 1) should be applied and the application of the procedure should be clearly documented.

Questions on the completeness of a set of scenarios were raised and it is inevitable that there will never be, in a strict sense, full assurance that all relevant scenarios have been identified.

A systematic screening of scenarios is needed to arrive at a limited set of really important scenarios for detailed analysis. Screening criteria were discussed and it was felt that some general guidelines based on physical reasonableness, regulations, preliminary risk estimates, etc. could be formulated in the report (see Annex 3). Also in this case the application would call for clear documentation of, for example, simple bounding calculations leading to rejection of a particular scenario.

19. Among the topical issues raised were time perspectives and the use of cut off times, the estimation/calculation of probabilities, human intrusion scenarios and bounding analysis ("what-if" calculations).

It was noted that there is at present no common approach to time perspectives. Time periods for institutional control for shallow ground disposal is normally assumed to last a few hundred years. Regulations in some countries, notably Canada and the USA, mention 10.000 years as the time period for which detailed safety evaluations have to be made. In other cases

assessments over 1 million years or more have been made. In view of predictions of astronomic and large scale geological events 10^7-10^8 years seems to be an absolute upper limit for any meaningful discussion of the possible future influence of a radioactive waste repository.

There are several possible approaches to estimation of probabilities ranging from strict axiomatic calculations to subjective estimates. A description of these approaches with examples will be included in the report. The importance of defining probabilities in a clear way was stressed, as was the need to make clear distinctions between for instance probabilities of events/processes, probabilities of scenarios and probabilities of health effects within certain scenarios. In this context, the group also discussed "risk dilution" i.e. the possibility of lowering the estimated "total risk" from a certain scenario by including cases where the consequences are nil rather than concentrating on the pessimistic cases within a scenario ("risk concentration").

Item 5: Plan for future work

20. The third day of the meeting was used to develop a structure for a final report. This "table of contents" is attached (Annex 3). David Hodgkinson undertook to provide a first draft for comments by WG-participants before the next meeting which is tentatively set to 9-11 May 1988. An overview document (about 20 pages) would be prepared for the next PAAG meeting in January.

21. The NEA Secretariat will make a further compilation of scenario questionnaires and draft a systematic presentation (catalogue) of all this material. A draft terminology will also be made for comments by the working group.

22. In order to provide the PAAG with an opportunity to discuss in detail the NEA work on scenarios a one-day topical workshop will be arranged at the next meeting of PAAG which will be held in Paris, 25-27 January. The working group proposed the following presentations for inclusion in the programme of such a topical workshop.

- Background information on the scenario work by NEA and questionnaire responses, by C. Thegerström, NEA
- Presentation of the Scenario Selection Procedure developed at Sandia and its application, by B. Cranwell, USA
- The role of scenarios in an approach using stochastic methods for time dependent simulation of the future of nuclear waste disposal systems and their environment (Brian Thompson, UKDOE, will be asked to make this presentation)
- Presentation of the NEA working group approach to Scenario Identification and Selection by D. Hodgkinson, UK.

The NEA Secretariat will prepare further a detailed programme for the PAAG workshop in contact with the Chairman of PAAG and the chairman of the

working group on scenarios. Ample time should be allowed for discussions. Background documents for the PAAG-meeting and for this one-day workshop are planned to be sent to Members of PAAG before mid December 1987.

23. It is planned to include in the report a worked-out example of scenario development for a chosen deep disposal concept. There is interest from Sweden (SKI and SKB) to support work based on a deep repository in crystalline rocks and possible arrangements and plans will be investigated further and presented at the next PAAG meeting.

24. The next meeting of the Working Group is planned to be held 9-11 May 1988 in Paris. This make it possible to obtain comments and further guidance on the work by the PAAG, which has its meeting in January and by the RWMC which has its next meeting end of March 1988.

Item 6: Other business

25. It is proposed that the working group participants (including NEA Secretariat) on their own initiatives send out reports and documents relevant as a background material for the work to be made.

Attached

- Annex 1: Graphical Illustration of Scenario Selection Procedure
- Annex 2: Overview of responses to NEA Scenario Questionnaire
- Annex 3: Draft table of contents for final document
- List of participants

ANNEX 1

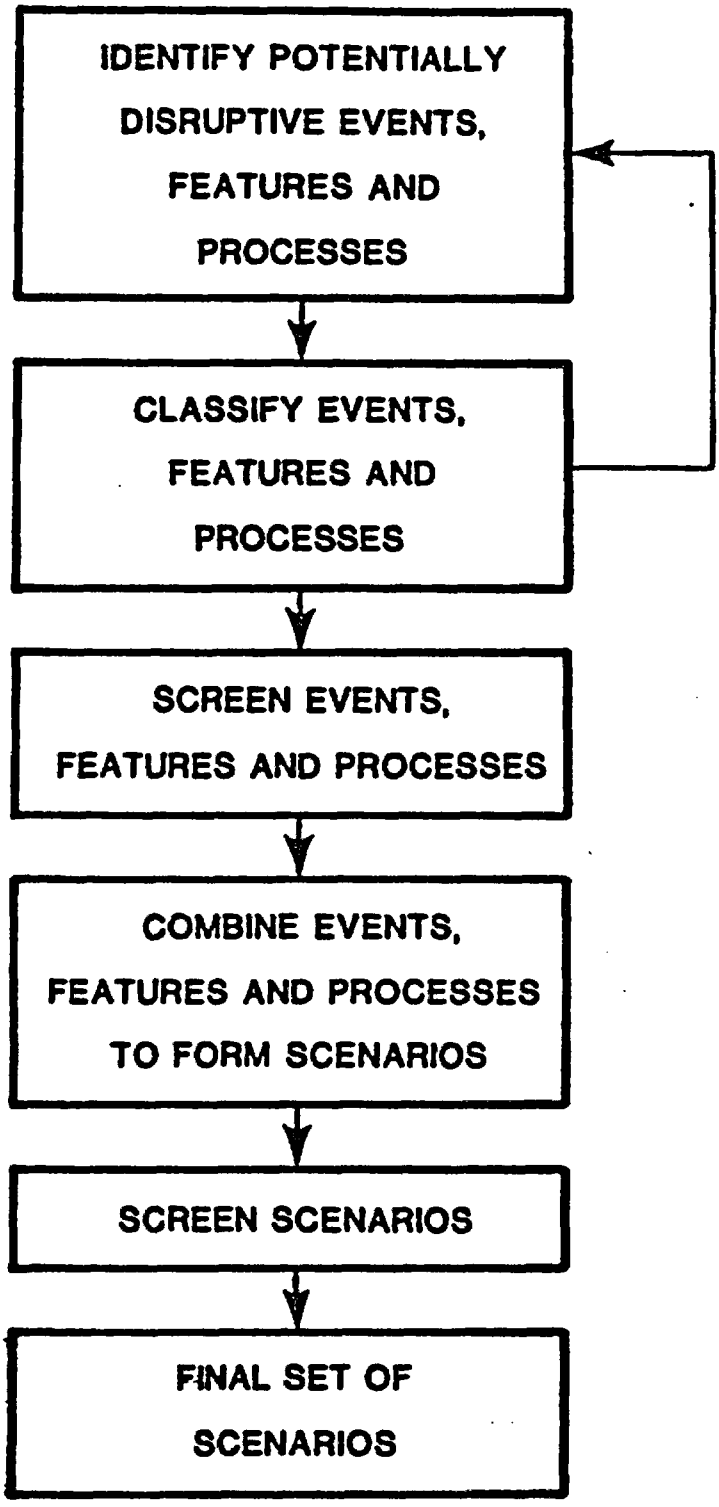

Fig. 1 Graphical Illustration of Scenario Selection Procedure
(from NUREG/CR-1667, SAND 80-1429)

ANNEX 2

Overview of Responses to NEA Scenario Questionnaire

By the end of October 1987 23 questionnaire responses were received from 10 Member countries. They cover scenarios and assessments for disposal of all types of radioactive wastes including also a case of disposal of uranium mill tailings. Table 1 below is an overview of the responses with a preliminary brief characterisation of them. The complete questionnaires are available at NEA and a comprehensive compilation of the existing and possible additional material will be made as part of the preparations for the working group document that is planned to include a questionnaire catalogue as an annex. Thus there is still time to provide questionnaire responses for those organisations who would like to do so and in that way have their studies included in the catalogue. Everybody that provide input to the scenario catalogue will get it in draft form for comments.

OVERVIEW OF RESPONSES TO NEA SCENARIO QUESTIONNAIRE

COUNTRY/AUTHORS	SITE & DISPOSAL CONCEPT	PURPOSE AND MAIN RESULTS OF PERFORMANCE ASSESSMENT	SCENARIO IDENTIFICATION METHODOLOGY	SCENARIOS SELECTED	REMARKS
BELGIUM					
Marivoet/Bonne SCK/CEN, Mol	Boom - Clay formation. Vitrified HLW disposal at 230 m depth in galleries or boreholes from galleries	A first evaluation of long-term safety. 50 m clay layer was found efficient to confine wastes. Thickness of clay-layer is important	Joint SCK/CEN & JRC Ispra study. Fault Tree Analysis (FTA) technique was used.	- Normal evolution - Well scenario - Climatic changes (precipitation) - Glaciation - Faulting (-Human intrusion)	One of the few studies using FTA to estimate probabilities of scenarios. 1980-83 1 manyear/year. 1984-87 2,5 " Internal review only. Review and update during the next years.
CANADA					
Stephens/Goodwin/ Wikjord AECL	Plutonic rock in Canada CANDU-fuel in Ti-containers, at 500-1000 m depth. Emplacement in boreholes from room-floor. Sand/Bentonite buffer.	To evaluate safety and to demonstrate methods. 3rd postclosure assessment as part of broader concept evaluation. 2nd post-closure assessment: no significant consequence for more than 10 000 years. Highest doses from I-129 in well scenario. The geosphere is the major barrier. SYVAC 3-CC3 will be main tool.	Judgement of the group performing the assessment and other members of the programme.	- Central scenario (= groundwater intrusion with several variations) others: - Glaciation - Seismic events - Criticality - Human intrusion - Volcanism - Meteorite Strike - Surface explosions - Undetected geosphere pathways.	Full probabilistic assessment (SYVAC) Simulations giving high dose will be analysed in detail. Elaborate review process is planned including public hearings.
Jarvis/Hardy AECL, Chalk River	Sand dune at Chalk River LLW disposal in engineered vaults below surface but above water-table.	To obtain approval to proceed with detailed design. Impact of Co-60, Cs-137 and Sr-90 well below reg. limits (= risk of less than $10^{-6}y^{-1}$). Institutional control for 50-100 years may be necessary.	Discussion and formal working parties covering a wide range of disciplines.	- Groundwater migration - Well drilling into underlying aquifer - Discovery intrusion - Escapes of gases/ vapour	Additional nuclides will be studied in next safety report. COSMOS-SID-code used and will be run in stochastic mode in later assessments. Probabilities of some intrusion scenarios will be considered

COUNTRY/AUTHORS	SITE & DISPOSAL CONCEPT	PURPOSE AND MAIN RESULTS OF PERFORMANCE ASSESSMENT	SCENARIO IDENTIFICATION METHODOLOGY	SCENARIOS SELECTED	REMARKS
CANADA (Cont.)					
Whitehead, AECB (Proponent: Eldorado Resources Limited)	Port Granby, Ontario. Till layers. Engineered burial of 600 000 m^3 Ra-U-refinery wastes. 300 x 30 m^2 x 10 m deep trenches with cap and cover options.	Scoping exercise. Exposure of waste or overflow could result in unacceptable doses. U and Th-230 were main contributors to dose.	Judgement by the group designing and performing the assessment.	- Release to surface waters (breach of cover of overflow) - Release of radon or particulates - Release to groundwater	Time cut-offs of 1000 y or 2000 y were applied
	Port Granby, Ontario. Cavern disposal of waste as above. Caverns located in bedded limestone at about 100 m depth.	Scoping exercise. Release via groundwater the only pathway. Contaminants migrated less than 1 m from facility in 2000 y. Improper sealing could result in unacceptable doses.	As above	- Leaching and seepage from cover into bedrock - Upward seepage via shaft to weathered zone and to a well.	"Conservative but realistic" input values used
Zgola/Whitehead AECB (Proponent: Eldorado Resources Limited)	Beaverlodge, Saskatchewan Shallow Lake disposal of 6 x 10^6 tonnes of uranium mill tailings.	To evaluate and select decommissioning options. Estimated individual doses were 1-10 mrem/y. Removal of tailings and disposal underground was not found justified based on cost benefit analysis. Stabilization procedures to prevent or reduce migration were adopted.	Joint consultation between the proponent and regulatory agencies.	Releases if - Removal and disposal of all tailings underground. - Complete watercover - partial watercover - Vegetation of tailings - Physical cover - Combinations of the above	Real case cost benefit analysis
FRG					
Storck, GSF	Gorleben, salt dome. Disposal level about 800 m. HLW in 300 m deep boreholes. Spent fuel in drifts. LLW in chambers.	To demonstrate the methodology (PSE). Deterministic, conservative assessment. No contact of intruding brine and HLW due to creep (high temp.). Release from HLW, LLW give 10^{-4}Sv/a after 6000 years.	Expert judgement. Selection of a single scenario for demonstration purposes	Brine intrusion via the main anhydrite.	Expected to be an 'umbrella scenario'. The importance of relevant phenomena (solubilities, dam permeability, temp. creep) will be considered for future repository design.

COUNTRY/AUTHORS	SITE & DISPOSAL CONCEPT	PURPOSE AND MAIN RESULTS OF PERFORMANCE ASSESSMENT	SCENARIO IDENTIFICATION METHODOLOGY	SCENARIOS SELECTED	REMARKS
FRG (cont.)					
	Konrad abandoned iron-mine. Host rock thickness 40 m/ 1200 m below surface. LLW, MLW disposal in excavated chambers.	Licensing procedure. Deterministic conservative assessment. Peak doses 10^{-4}Sv/a after 300 000 y.	Expert judgement.	- Normal evolution for undisturbed site - Preferential pathways through drillholes or shaft.	Review process included in the licensing procedure.
	Asse salt dome. LLW, MLW in chambers from former mining between 490-750 m in depth.	Preliminary study to define necessary R&D work. Deterministic conservative assessment. Results not yet published.	Expert judgement. Selection of a single scenario for demonstration purposes	- Deformations give pathways for unsaturated brine into backfilling repository.	Expected to be an umbrella scenario.
	Gorleben, salt dome. Vitrified HLW disposal in boreholes of 300 m depth, disposal level 800 m.	To demonstrate the methodology (PAGIS). Probabilistic assessment. Results not yet published.	Expert judgement.	- Intrusion of saturated brine via main anhydrite - Intrusion via shafts or flank of the dome - Human intrusion by solution mining	
FINLAND					
Vieno, VTT Peltonen, TVO	Olkiluoto, Crystalline bedrock Disposal of spent fuel encapsulated in Cu-canister in deposition holes with bentonite buffer at 500 m depth.	Feasibility study. Conservative assessment. All cases were below $10^{-5}y^{-1}$ health risk. Performance of any single barrier is not critical.	Judgement by the team performing the study. IAEA check list was used	- Basic scenario - Disturbed evolution (initial canister failure, oxidising cond. in geosphere, ...) - Disruptive events (major rock movement, exploratory drilling).	Probabilities of postglacial block movement and human intrusion were estimated. Review by authorities has been made A "wise men group" will be established to review scenario selection.
Vieno, VTT	Loviisa, crystalline rock. LLW disposal in rock caverns at about 100 m depth.	Licensing (PSAR). Maximum individual doses conservatively estimated to be below 10^{-5} Sv/y in all cases.	Judgement by the team performing the study. IAEA check list was used.	- Basic scenario - Changes is local groundwater conditions - Rapid degradation of engineered barriers - Land uplift and sea level changes	Probabilities were estimated for well drilling and disruptive events due to seismics. Total loss of performance of engineered barriers is considered as a "worst case" scenario. The PSAR was given to authorities in December 1986 for review.

COUNTRY/AUTHORS	SITE & DISPOSAL CONCEPT	PURPOSE AND MAIN RESULTS OF PERFORMANCE ASSESSMENT	SCENARIO IDENTIFICATION METHODOLOGY	SCENARIOS SELECTED	REMARKS
Finland (cont.)					
Vieno, VTT Peltonen, TVO	Olkiluoto, crystalline rock. LLW disposal in rock caverns at 50-90 m depth.	Licensing (PSAR). Maximum individual doses conservatively estimated to be below 10^{-6} Sv/y in all cases.	Judgement by the team performing the study. IAEA list was used.	- Basic scenario (conservative or realistic data) - Rapid degradation of eng. barriers - Water filling of gas lock - Earthquakes - Land uplift	See above
FRANCE					
Levi, CEA	Crystalline rock in France (Auriat, Barfleur) or in UK. Vitrified HLW stored for 30 or 100 y disposed of in boreholes at depth. Bentonite backfilling	Feasibility study for selected formations and repository designs (PAGIS, CEC). MELODIE-code used. Results to be published by CEC	Expert judgement.	- Normal evolution scenario - Altered scenario (= human intrusion by mining close to repository)	Best estimate parameter values + uncertainty/sensitivity analysis. Shaft or borehole sealing failure, initial canister failure, faulting and glaciation will be considered in the future.
JAPAN					
Yuki, JAERI	Rokkasho-mura. Shallow land disposal of LLW.	License application to start at site. Assessment and results still pending.	-	-	In response to burial operators application authorities are preparing safety assessment methodologies and regulatory guidelines.
	Disposal of vitrified HLW at depth. Multibarrier system.	Prel. performance assessment, design review, evaluation of R&D work. Results still pending.	Reference to international studies. A domestic group will be set up to give advice.	- Base case - Uplift or sink of geosphere - Earthquake	Time-span divided into short (1000 y) medium (10 000 y) and long term (>10 000y). A national review committee has been set up. International review is also planned.

COUNTRY/AUTHORS	SITE & DISPOSAL CONCEPT	PURPOSE AND MAIN RESULTS OF PERFORMANCE ASSESSMENT	SCENARIO IDENTIFICATION METHODOLOGY	SCENARIOS SELECTED	REMARKS
SWEDEN					
Papp, SKB	Swedish crystalline rock study site. Spent fuel encapsulated in Cu-canisters disposal (500 m depth) in deposition holes. Bentonite buffer.	Feasibility study required by the law (KBS-3). Deterministic conservative assessment. After extensive national and international review the concept was considered by the Government to be acceptable.	Judgement within the group performing the study. (Including experts in a variety of relevant areas).	- Reference scenario (with 4 subscenarios on recipient) - Initial canister failure - Oxidized geosphere - High colloid fraction - Land rise - Earth quake (rock displacement) - Criticality - Glaciation, Meteorite impact, human intrusion	The transition from feasibility studies to comparison of concepts and optimization will require more systematic approach and less conservatism. Probabilistic methods will also be used in future.
Andersson, SKI	See above	Complementary studies in reviewing of KBS-3 study. Parameter variation + effects of barriers studied. KBS-3 method considered feasible. Canister, buffer and geosphere barrier must all function in the early stage after disposal. More research needed before implementation.	Judgement in complement to above	- Variations of reference scenario and initial canister failure scenario.	SKB choice of scenarios was not seriously critisized.
SWITZERLAND					
Hadermann, EIR McCombie, NAGRA	Crystalline basement in Nothern Switzerland overlayed by several 100 m of sediments. Vitrified HLW in thick iron canisters disposed in drifts at 1300 m depth.	Feasibility study (Project Gewähr) required by law. Deterministic assessment with parameter variations. Calculated doses far below limits. Remaining questions concern representativity of data and model validation.	Judgement within the group performing the study. Help of specialists in particular fields. Systematic classification of events and processes.	- Base case scenario + parameter variations - Well in upper crystalline - Extreme climate - Others (erosion, vulcanism, meteorites, earthquakes, tect. movements, decompression around rep., shaft failure, colloids/microbes, etc. considered qualitatively)	Basis for scenario identification will not change much. Quantitative probabilistic aspects will be introduced in future assessments.

COUNTRY/AUTHORS	SITE & DISPOSAL CONCEPT	PURPOSE AND MAIN RESULTS OF PERFORMANCE ASSESSMENT	SCENARIO IDENTIFICATION METHODOLOGY	SCENARIOS SELECTED	REMARKS
Switzerland (Cont.)					
Zurkinden	See above	Critical review of Project Gewähr. The most important open question concern existence of sufficiently large rock bodies for which used data apply. Disposal in other rocks than the basement should also be evaluated.	External experts used to give judgement.	- Basic scenario with variations - Nat. Processes and events (climatic changes, erosion, tectonic movement, others)) - Repository induced scenarios (early canister failure, failure of backfill or shaft sealing, colloids/micro-organisms,...) - Human induced scenario (extraction of materials or water, mod. of flow path or sorption cap.)	Uncertainties gave variations in calculated dose of 8 orders of magnitude. Migration barrier gave large variation with uncertainties. Alternative scenarios were treated only qualitatively. Extension of present guidelines by some probabilistic element is forseen.
Van Dorp, NAGRA	Anhydrite, Alpine marl (Oberbauenstock) or crystalline site. Disposal of LLW and MLW in caverns with horizontal access in a mountain. Different options of engineered barriers.	Feasibility study (Project Gewähr) Deterministic assessment. The study showed that disposal of LLW/MLW should be possible without exceeding regulatory limits (individual dose < 0,1 mSv/y). Erosion scenarios caused the highest doses. (Erosion could occur within 10^5-10^7 y).	Expert Judgement. IAEA list was used.	- Natural processes (water transport, climate changes, erosion) - Natural events (earthquakes, floods, faulting) - Waste and repository effects - Human activities	If possible scenarios were treated as parameter variations of the base case scenario. Erosion scenarios were taken into account in site selection. Gas release scenarios influences the design of eng. barriers. More emphasis in the future on erosion and human intrusion scenarios. Probabilistic aspects will be introduced.
Zurkinden	See above	Review of Project Gewähr study. The safe disposal was found feasible. Disposal of α-bearing waste sets however higher requirements on the long-term integrity of the geological barrier	Judgement by the group performing the study.	- Basic scenario with variations - Natural processes and events (glaciation, dry climate, landslide, natural gas) - Repository induced scenarios (Gas displacement, colloids, impairment of migr. barrier) - Human intrusion (drilling, tunneling)	A thorough quantitative assessment of identified scenarios is asked for in the project phase. Need to extend present guidelines by some probabilistic element.

COUNTRY/AUTHORS	SITE & DISPOSAL CONCEPT	PURPOSE AND MAIN RESULTS OF PERFORMANCE ASSESSMENT	SCENARIO IDENTIFICATION METHODOLOGY	SCENARIOS SELECTED	REMARKS
UNITED STATES					
Guzowski, SANDIA	Yucca Mountain tuff site in unsaturated zone. Spent fuel in stainless steel canisters. 200-300 m below surface and 200-400 m above water table.	Demonstration of performance assessment methodology. Results not yet available.	Expert judgement with systematic listing and screening of events and processes. Combination of events/ processes result in scenarios.	- Base case (including also migration of gaseous radionuclides) - Pluvial conditions with several variations (faulting, perched water table, withdrawal wells, ...)	Probabilities physical reasonableness used in screening process. Work done for USNRC.
Cranwell, SANDIA	Hypothetical bedded-salt site being representative of several regions in the US. Vitrified HLW disposal at 700 m depth.	Demonstration of performance assessment methodology. The study showed, for scenarios and data used that EPA standard would be violated.	See above	- Base case (undisturbed conditions) - Scenarios combining different hydrological conditions including wells, U-tube conditions and dissolution cavity above repository - Drill shaft intersecting canister surroundings	Probabilistic assessment. Most of the probability models and data are very site specific. Subjective estimates of probabilities by expert is the best approach in many cases. Work done for USNRC
Bonano, SANDIA	Hypothetical basalt site representative of NW United States. Vitrified HLW waste disposal at about 900 m depth.	Demonstration of performance assessment methodology. Simple solubility limited source term was used. Groundwater travel time criterion was met. Sensitivity analysis showed radionuclide transport dependence on matrix diffusion and gr. water travel time.	See above	- Groundwater travel time calculation - Change of river location - Groundwater pumping - Drilling through repository - Faulting - Heat effects - Glaciation	Data uncertainties was taken into account in a probabilistic manner.
UNITED KINGDOM					
Grimwood	Drigg site. Shallow burial of LLW in trenches in clay 1 m topcover. From 1988 disposal will be in concrete lined vaults.	To guide further research and investigations and to form a basis for site authorisation. Overall risks assessed to be less than 10^{-6} y^{-1} (Reg. limit).	Expert judgement through review of previous studies and consideration of site and waste-specific conditions.	- Groundwater release scenarios - Gas release of H3, CI4, Ra222 - Human intrusion (boreholes, excavation etc.) - Well withdrawal from cont. aquifers - Fire during operations	Well scenario probability based on current rate of sinking wells in the region. Intrusion probability also estimated. Glaciation and erosion to be studied also.

COUNTRY/AUTHORS	SITE & DISPOSAL CONCEPT	PURPOSE AND MAIN RESULTS OF PERFORMANCE ASSESSMENT	SCENARIO IDENTIFICATION METHODOLOGY	SCENARIOS SELECTED	REMARKS
UK (cont.)					
J. Jowell (on behalf of NIREX ass. team)	Sedimentary formation with clay as host rock. Near-surface (5-20 m below ground-level) disposal of LLW in concrete vaults. 300 y institutional control	To aid in selecting a repository design and site able to satisfy reg. criteria. Due to a change in national policy the studies are not fulfilled beyond the preliminary stage. Preliminary analysis of human intrusion scenarios gave estimated peak individual risks of about $10^{-6}y^{-1}$ (regs. limit) to up to $3.10^{-5}y^{-1}$ for a repository with only 5 m cover.	a) use of IAEA list b) personal imagination c) group disc. in saf. ass. meetings d) classification by cause and exposure route	The following categories were selected: a) groundwater transport b) intrusion c) gaseous transport d) nat. disruptive events.	To illustrate uncertainties due to subjective aspects of assessing human intrusion it was planned to have to independent groups address the same scenario. 10^5y used as cut-off. Future work will be on deep site concepts. Scenario interaction will be considered in the future.
INTERNATIONAL seabed Working Group (OECD/ NEA	Disposal of HLW in steel penetrators 50 m into the sea-bed (4000 m depth) in the Atlantic Ocean. 15000 penetrators 100 m apart, corresponding to 10^5 t spent fuel	To assess the safety of the seabed concept. The study indicate that seabed disposal is a very safe option. Further research should aim at model validation for porewater migration, retention properties in sediments etc...	Expert judgement	a) Base case scenario b) Abnormal scenarios - penetrator depth < 10 m - upward pore water velocity in sediments c) $K_d = 0$ in sediments	Calculations were made simultaneously and independently by different institutions in several countries. A consistent set of models and a single data base was used.

ANNEX 3

TABLE OF CONTENT FOR NEA REPORT ON SCENARIOS

(DRAFT)

1. INTRODUCTION

- Sources and characteristics (scheme) of radioactive waste will be briefly described.
- The long time perspectives will be mentioned. Hence the need of scenarios (possible futures) to assess the long-term safety.
- Safety approach of nuclear waste disposal compared to toxic waste disposal will be mentioned to give the broad perspective.
- The purpose of the report and the role of NEA and PAAG.

2. FRAMEWORK OF PERFORMANCE ASSESSMENT

- Purpose of performance assessment.
- Regulations.
- Structure and elements of performance assessment (diagram).
- Reference to Appendix 1 (compilation overview of questionnaire responses and assessments made in NEA Member countries).
- Role of scenarios in performance assessment.

3. STRUCTURE OF SCENARIO DEVELOPMENT

- History and state of the art (ref. App. 1) (IAEA, NRC-Sandia, NEA WG).
- Conclusion: much has been done but more systematics is needed.
- Expert judgement fundamental (+ systematics).
- Procedure diagram (Sandia). This is the overall structure and applications might vary.
- Discussions of definitions with examples (what is a scenario and what is not). Distinctions.
- Discussion of completeness and transparency (QA, traceability, understandability).
- Discussion of probabilities (listing of calculation/estimation methods, preliminary and refined calculations, etc.). Reference to Appendix 2 for more details.

4. COMPONENTS OF SCENARIO DEVELOPMENT

- Introductory words of wisdom. (The procedure outlined in this chapter gives a systematic structure to be used for development of scenarios by expert opinion. Feedback important).

4.1 Identification of Features, Events and Processes (FEP:s)

- Definitions
- Completeness
- Types of people involved
- List of FEP:s for deep disposal (lists for near-surface and seabed FEP:s will be given in Appendix 3)
- A word about unconscious screening, thoroughness, completeness
- Timescales, natural analogues.

4.2 Classification of FEP:s

- This closely interacts with the identification of FEP:s and it helps to address the thoroughness issue
- Examples of classification:
  . human, natural, repository
  . short-term, long-term
  . release (near-field), transport (geosphere), exposure (biosphere)
  . according to scientific disciplines (chemistry, geology, etc.).

4.3 Screening of FEP:s

- Site and system specific
- Examples of screening criteria
  . physical reasonableness
  . regulations
  . probabilities
  . bounding consequence analysis
  . incremental consequences
  . cut-off time

4.4 Combine FEP:s to form scenarios

- All combinations of FEP:s (completeness)

- Examples of methods
  1. Logic diagrams
  2. Influence diagrams (?)
  3. Event trees
  4. Fault trees

4.5 Scenario screening

- Site and system specific
- Consider time-sequence
- screening criteria
  . physical reasonableness
  . regulations
  . probabilities
  . bounding consequence analysis
  . incremental consequence

4.6 Scenarios for Consequence Analysis

- Consequence modellers should be directly involved (model dependent)
- Grouping of related scenarios
- Identification of scenarios that need model and data development
- Priorities
- Specification for modelling
- Example 1 (worst time sequences)
  Example 2 (stochastic time sequences)
- Reminder of probabilities

5. RECOMMENDATIONS AND CONCLUSIONS

- Be systematic
- Document all steps
- Traceability, understandability
- Broad interaction (e.g. review)
- Iterate
- Early interaction with R&D and site investigations, repository design and site investigation/selection.

APPENDICES

1. QUESTIONNAIRE CATALOGUE

2. ESTIMATION/CALCULATION OF PROBABILITIES

3. LISTS OF FEATURES, EVENTS AND PROCESSES FOR SHALLOW DISPOSAL AND SEABED DISPOSAL

4. COMPLETE EXAMPLE OF SCENARIO DEVELOPMENT FOR A CHOSEN DEEP DISPOSAL CONCEPT

5. GLOSSARY

WORKING GROUP ON SCENARIOS

12th- 14th October 1987

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